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Teacher mediation actions and students' productive engagement during the use of computer simulations in physical science classrooms

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Abstract

In this study, we intend to characterize the productive engagement of students during the use of computer simulations in the classroom, and identify and describe the factors that influence it. Our principal aim is to understand how the teacher's mediation in classroom with students using computer simulations influences the students' productive engagement. There are described two teacher cases. It was collect several types of data about two lessons per teacher. The two teachers of physics and chemistry have similar professional experience, but different experience integrating educational research in their teaching practices. The results allow us to find the fundamental conditions to engage students productively when they use CS and the main differences between the mediation of two teachers**.**

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Keywords: Students produtive engagement; Teacher mediation; Computer Simulations; Physical science classroom.

1. Introduction

The main purpose of this study is to highlight the relationships between the teacher mediation actions [1,2,3] and

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student's productive engagement in their work [4,5] during the use of computer simulations [6,7] in the physical sciences classroom. In particular, we intend to study how teacher's mediation influences the students' productive engagement during the use of CS. We intend investigate if factors such as the theme and content of the lesson, the tasks proposed and its management in the classroom, and the type of computer simulations have influence over teacher mediation actions and, consequently, over the students' productive engagement.

The difficulties that many students have in understanding physical phenomena are well known and teacher feel the need to adopt diverse teaching methodologies to overcome these difficulties, including the increasing use of computers in the classroom [8]. Computer simulations (CS) can help students to engage productively in physical sciences lessons and are referenced as appropriate tools for promote students engagement [9]. However, the fact that computers are present in the classroom does not necessarily mean that students effectively use them for work productively and learn with them [10].There are many studies about the potential benefits of using CS for learning in physical sciences classrooms [11] but there are few studies that focus attention on teaching practices with the use of CS [7].

The teacher mediation in the classroom has certain characteristics that can lead students to productive engagement in the tasks [12]. This research is based on the work of Engle and Conant [4] that suggest four guiding principles to promote the productive engagement of students.

Previous results of studies conducted by our research team [e.g.,12,13,14] highlight that the most determinant teacher mediation actions that promote student engagement in a productive way are given authority to the students and keep the task as a challenge, assuming that the task was designed and placed as a challenge. Teacher may have several ways to keep the task as a challenge (manipulating resources for students can use them proficiently; induce students to have a more conscious and systematic asking them clarifications) and various forms of giving authority to students (allow students to perform tasks with autonomy and responsibility and giving incentives to engage productively). The task must give to students acceptable control over their activity and they must know exactly what they need to do for achieve an answer or solution [15].

On the other hand, the characteristics of the teacher's teaching practices depend on many factors, but perhaps the most important is how to integrate several kinds of knowledge on their professional practice [9,16]. The experience of participating as researcher in science education projects, gives explicit professional knowledge [17] for being attentive to some important research results about teacher mediation actions and integrating them in their professional practice. Thus, it is expected that two teachers with identical professional experience and identical initial training, but different experiences of participation in research projects in the field of science education, have important differences in their mediation actions in the classroom. Additionally, studying the teacher mediation in the classroom, during the student's accomplishment of the tasks that use CS allows the identification and description of the characteristics of teacher mediation actions which are determinant for promote students productive engagement during the use of computer simulations and his effective engagement during the tasks.

In particular, we are interested to focus on how teacher's mediation when students use CS in classroom influence the students' productive engagement and how factors such the topic and content of the lesson, the tasks proposed and its management in the classroom and the type of CS influence teacher's mediation. Taking that into account, the research questions that guide this research study are the following:

a) How to characterize the productive engagement of students during the use of computer simulations in the classroom?

b) What factors (type of CS used, tasks, task management, and content of the lesson, teacher experience in research) have influence on teacher mediation actions to promote students' productive engagement during the use of CS in the classroom?

c) What are the main connections patterns between teacher's mediation and students' productive engagement during the use of CS in the classroom?

2. Methodology of Research

This is a research work with a qualitative and interpretative nature, with two case studies [18] involving two physical sciences teachers from secondary school (students age 15-18 years) with same teaching experience, same academic degrees, and different practice in research in the field of physical sciences education of what happens in the lessons taught by two teachers from different public schools from Portugal, all about Chemistry (10^{th} grade), and

in both lessons students develop inquiry work organized into small groups. The main characteristics of the case studies are presented in table 1.

Table1: Main characteristics of case study teachers

Teacher		A	B
Gender		Female	Female
Academic degree		PhD student	PhD student
Teaching experience		23 years	22 years
Research experience		Yes	No
1st Lesson	Topic of lesson	Photoelectric effect	Photoelectric effect
	Tasks	19	2
	Task management	All tasks presented at the beginning of students work	Each task presented in different moments of students work
	Time of lesson	135 min	135 min
	CS used	PhET: "photoelectric effect"	PhET: "photoelectric effect"
2nd Lesson	Topic of lesson	Blackbody radiation and Wien Law	Blackbody radiation and Wien Law
	Tasks	2 tasks (same tasks for both teachers)	2 tasks (same tasks for both teachers)
	Task management	Each task presented in different moments of students work	All tasks presented at the beginning of students work
	Time of lesson	120 min	60 min
	CS used	PhET: "Blackbody-spectrum"	PhET: "Blackbody-spectrum"
Inquiry work		Yes	Yes
Group work		Yes	Yes

2.1. Data collection

It was collected several type of data from each lesson, including audio recording, documents, used or produced by teacher or students, printscreens, photos, teacher notebook. Based on these data it was produced four (one per lesson) multimodal narratives [19]. The multimodal narratives (MN) analysed correspond to the lessons taught by the two teachers during the use of CSs available on web (PhET): in two lessons were used the "Photoelectric effect" (one lesson for each teacher) and in the other two (one per teacher) were used the "Blackbody-spectrum". A MN is the description of what happens (actions, languages, decisions, etc.) inside the classroom having as reference the tasks proposed and their development, the data collected and multimodal elements (e.g. print screens of CS, student reactions, explicit teacher's intentions and decisions, students' notebook, teacher's documents, photos, indication of silences and gestures). The MNs have all the same structure and the same focous (the development of the tasks in the classroom) in order to allows its comparability, and are all made by teachers themselves.

2.2. Data analysis

The analysis of multimodal narratives (MN), based on content analysis [20] were determined by theoretical framework mentioned above and focus on the following dimensions: (a) teacher mediation actions to engage students in the tasks, (b) engagement of students in the discipline, and (c) indicators of student's productivity. However, the dichotomous variables found for each dimension were determined by *open code* analysis [18,21] of the MN. The NM were analyzed by a researcher using qualitative software analysis (NVivo 8®). From each MN were identified dichotomous variables related to evidences about teacher mediation actions (Table 2), about students' production (Table 3) and student's productive engagement while using the CS (Table 4).

Table 2: Teacher mediation actions identified in MN

Variables	Definitions used for encoding
Propose task as a challenge	Place an authentic task, contextualized and relevant to students.
Propose task	Request some kind of activity but not as challenge.
Reformulate the task	Request aspects that are not fully disclosed from the beginning of the task.
Place subsidiary task	Place another task for maintain the task challenging.
Corrects students engagement	Facing the indicators of disengagement, directly demand the engagement. Stimulate curiosity and give support if necessary.
Monitor the engagement	The teacher is attentive at the indicators of students disengagement.
Make present previous information	Engage students by helping them to recall information worked out in earlier times.
Engage students in the task	Make sure students understand what they need to do to accomplish the task and explicit its relevance.
Keep the task as challenge	Preserve the initial characteristics of the task, even during interactions with students.
Don't keep the task as challenge	Don't preserve the initial characteristics of task, when interacting with students.
Encourage students engagement	Teacher in a preventative way, encourage, give positive feedback, praise, ensure that students have confidence to accomplish the tasks.
Inform about the CS	Provide information or directions about how to use the CS.
Give authority to the students	Allow students to have autonomy, take initiatives and have control over the tasks.
Remove the authority from students	Give too many clues or get involved in students' work, depriving them the opportunity to be autonomous
Provide resources	Provide resources that allow students to work autonomously
Stimulate problematizing	Allow or encourage students inquiry (problematizing about of physical situations, formulate questions, planning investigations)

Through the evidences collected was made the first attempt of coding. Each encoding receives a brief description and as the respective definition. After coding being revised the definitions were refined and checked if the selected excerpts of MN were well described by each encoding. During this process, each encoding, as well as their definition was not definitive. Some encodings can be grouped into one, or may be split. Each excerpt can be described by various encodings. After accomplish this process, each encoding earns the status of dichotomous variable. That is, each passage is characterized by the presence or absence of each one of the variables found by open code analysis. This analysis was reviewed by two independent researchers.

The degree of agreement was 94%. In the remaining cases, a refinement was made to obtain complete agreement. After this phase the categorization was made by the investigators, which corresponded to revisit MN using dichotomous variables. The variables determined by the open code analysis and defined briefly presented in Tables 2, 3 and 4.

The second order analysis allows answer the research questions. To this end, we selected units of analysis adopting a timescale [3] called the episode. This unit of analysis selected from each MN includes all dichotomous variables about the teacher mediation to engage students productively, dichotomous variables about the engagement / disengagement and about student production that have occurred between the moment of task proposal and its accomplishment.

All dichotomous variables (Table 2, 3 and 4) determined by open code analysis, were used to build matrixes on the episodes of the two teachers, related or not with the use of computer simulation. For all variables we considered the presence (indicated by the value "1, 2, ..." according to the number of times occurring) or the absence (marked with value "0") during the episode. After construct the matrixes they are subjected to cluster analysis [20] with the software STATISTICA (StatSoft®). We constructed five matrixes and analyzed the correspondent dendograms: (a) one for teacher A episodes from both lessons (different CS, different content of the lesson, different tasks and different task management); (b) one for teacher B episodes from both lessons; (c) one for the episodes from the first lesson of both teachers (same CS, same content of the lesson, different teacher mediation actions, different tasks and different tasks management); (d) one for the episodes from the second lesson from both teachers (same CS, same theme, same tasks, different task management and different teacher mediation actions); (e) one dendogram for all the episodes from the two lessons of both teachers (Fig. 1).

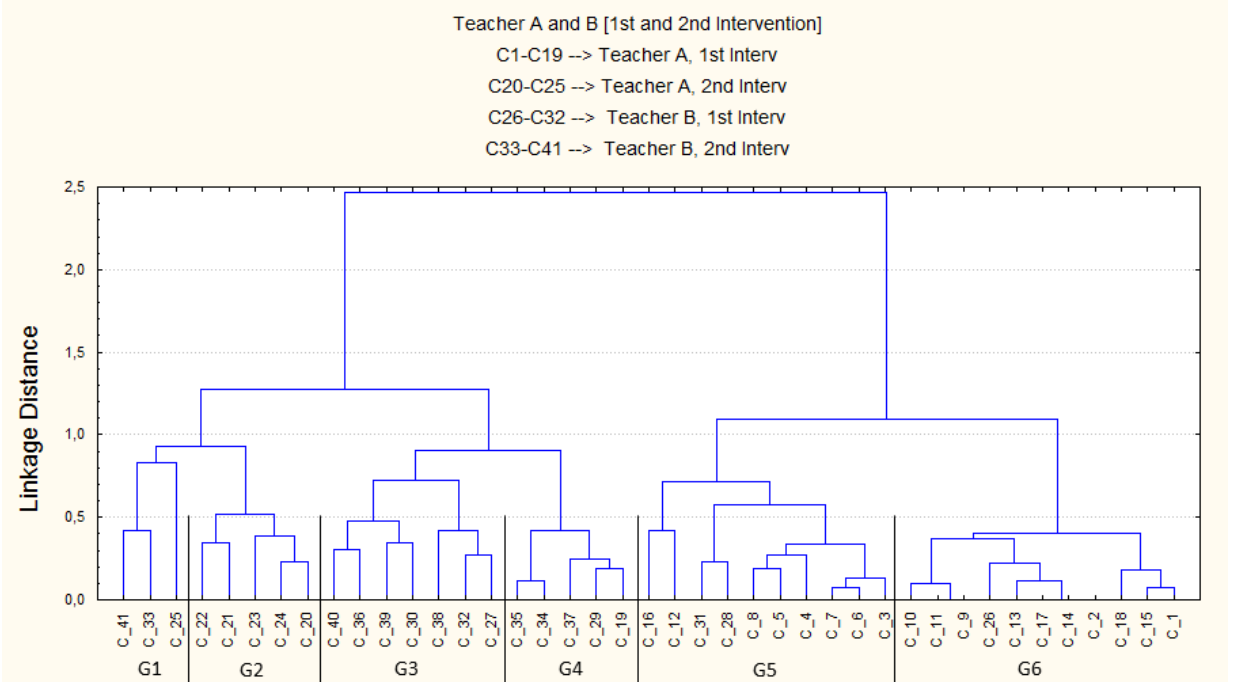


Fig. 1. Dendogram for all episodes from the two lessons of both teachers

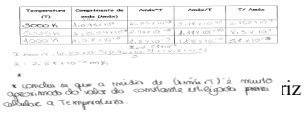
3. Results

3.1. Characterizing students engagement in classroom using CS

From the content analysis of multimodal narratives we identified evidences about students production during the use of CS (oral, writing or actions). Some examples of those evidences are presented in table 3.

From the content analysis of multimodal narratives we also identified evidences about students' engagement during the accomplishment of the task, about their emotional engagement and evidences about students' initiatives.

Table 3. Evidences about student's production

Variables	Definitions used for encoding	Evidences from MN
Writing	The product of the task is displayed in writing form (text, performing calculations, charts, descriptions)	**Teacher B** 
Oral	The product of the task is presented on the oral form (the student ask questions, hypotheses, argue, makes comments)	**Teacher A** [...] John explained well and the results show that the knowledge was consistent. He says that λ times T always gives the same value, that is 3x108 (meter x kelvin) and corresponds to the value of B, which was according to the Wien law. [...]
Actions	The product of the task is something observable in a non-verbal way, like handling the CS, choose modes of operate the SC)	**Teacher B** […] Gonçalo take into account teacher suggestions is already working with de simulation and is placing the temperature values and measuring with more accuracy the correspondent wavelengths […]

We also identified the moments when students were not engaged in the classroom work. Some examples of those evidences are presented in tables 4.

Table 4. Evidences about students' engagement / non-engagement

Variables	Definitions used for encoding	Evidences from MN
Emotional engagement	Show signs like enthusiasm, persistence in accomplish the task, etc…	**Teacher B** [...]The teacher told her students they could go into the break, however most of them decide to stay in the classroom and continue their work [...]
Students initiative	Take initiative in his actions such questioning, making or proposing something, etc…	**Teacher A** [...] There were groups who have decided to register another line in the table of results, as in the simulation could obtain data from four different bodies [...]
Engagement in accomplish the task	Engage through dialogue, recording, viewing images, performing activity, etc…	**Teacher A** [...] Rita said yes and showed the print screens of her group [...]
Non-engagement of the students	Show signs like being distracted, talking with colleagues, don't understand what is intended, etc…	**Teacher A** [...] Teacher says: - Daniel, I'm only hear you talking with your colleagues and doing clowning things? [...]

3.2. Factors that influence teacher mediation

The photoelectric CS provides to students a higher degree of interactivity than radiation CS. Also provide to students an environment less abstract and with more possibilities of visualisation of the phenomena. In fact the photoelectric CS environment provide, instead of radiation CS, an environment easily recognizable by students and allow the visualization of certain aspect of phenomena that in the correspondent material reality is not visualized. These main differences between the two CS explain how the frequency of non-engagement of students is greater in the lessons with radiation CS (with the two teachers) than in the lessons with photoelectric CS (with two teachers) (see table 5). In the radiation CS, the students do not observe the phenomena and they should lead with graphs, the main output of the CS, and consequently the students were not engaged.

Table 5. Indicators of students' engagement

Indicators	Teacher A		Teacher B	
	1st lesson	2nd lesson	1st lesson	2nd lesson
Frequency of emotional engagement	2,2	2,5	0,0	2,0
Frequency of students initiative	2,2	3,5	1,3	4,0
Indicator of engagement in accomplish task	4,7	3,2	6,4	1,7
Frequency of non-engagement of students	0,4	6,0	0,0	6,0
Acts of writing	4,4	4,0	1,8	3,0
Indicator of oral	11,3	5,7	19,3	3,2
Indicator of actions/management	7,1	13,3	22,5	6,0

In general, in teacher A lessons the students use the CS more effectively. There are more evidences about their emotional engagement and few evidences about non-engagement moments. We also verify that students have more production, especially during the second lesson. The products of the tasks are of all kinds (oral, writing and actions) and all are related with the effective use of the CS.

In general, during teacher B lessons, students use the CS in a less effective way. The student's actions and products of the tasks aren't all related with the use of the CS. There aren't any evidences during teacher B lessons about student's emotional engagement and there are more moments of student's non-engagement than in the lessons of teacher A. Also, during teacher B lessons students are less productive. They have oral production and acts, but they have a little writing production. The three types of productions don't appear simultaneously.

3.3. Patterns of connections between teacher's mediation and students' engagement

From the cluster analysis of data from the episodes of both lessons for each teacher we identified seven groups of connections between teacher's mediation and students' engagement. Identifying the variables that are characteristics of each group and interpreting the relations among them we identify for each group the patterns of connections between teacher's mediation and students' productive engagement (see table 6).

The information about number of episodes and about the lesson (1st or 2nd) allow us verify if a pattern occur only with one teacher and in a given intervention (e.g. G1, G2, G3) or is characteristic of a teacher occurring in any intervention (e.g. G4).

Teacher A mediation actions were affected by the type of task (2 tasks in 2nd lesson and 19 in 1st lesson). The differences of task management from lesson 1 to lesson 2 seems that don't affect the teacher mediation. The teacher mediation of teacher A is quite different from 1st to 2nd lesson (instead of teacher B that has some patterns that occur in 1st and 2nd lesson; (G4 and G5).

Despite the differences between the two lessons taught by teacher A, there are some mediation actions that stay the same in both lessons: always give authority to students and provide resources.

Table 6. Patterns of connections between teacher's mediation and students' productive engagement

Pattern	Teacher mediation actions	Students Engagement
G1 (2eTB; 2nd)	Propose a task as challenge; Give authority to students, but there are moments when takes it back; Provide resources; Give information about the CS; Engage students in the task; Not always keep the task as challenge; Monitor the engagement; Correct students' engagement.	Oral production and actions; Engagement in accomplish the task; Students non-engagement; Emotional engagement.

G2 (1eTA, 2nd)	Propose a task as challenge; Reformulate the task; Place subsidiary task; Give authority to students; Give information about the CS; Provide resources; Engage students in the task; Encourage the students' engagement; Stimulate problematizing; Keep the task as challenge; Correct students engagement; Monitor the engagement.	Oral production, written and actions; Engagement in accomplish the task; Students non-engagement; Emotional engagement; Students' initiative.
G3 (5eTA; 2nd)	Propose a task as challenge; Give authority to students; Provide resources; Engage students in the task; Encourage the students' engagement; Keep the task as challenge; Correct students engagement; Monitor the engagement.	Oral production, written and actions; Engagement in accomplish the task; Students non-engagement; Emotional engagement.
G4 (3eTB; 1st) (4eTB; 2nd)	Propose a task as challenge; Give authority to students, but there are moments when takes it back; Give information about the CS; Make present previous information; Provide resources; Engage students in the task; Encourage the students' engagement; Stimulate problematizing; Not always keep the task as challenge.	Oral production and actions; Engagement in accomplish the task; Students' initiative.
G5 (1eTA; 1st) (1eTB; 1st) (3eTB; 2nd)	Propose a task as challenge; Give authority to students; Give information about the CS; Provide resources; Engage students in the task; Encourage the students' engagement; Not always keep the task as challenge.	Oral production; Engagement in accomplish the task.
G6 (8eTA; 1st) (2eTB; 1st)	Propose a task as challenge; Give authority to students; Provide resources; Encourage the students' engagement; Keep the task as challenge.	Oral production and actions; Engagement in accomplish the task.
G7 (10eTA; 1st) (1eTB; 1st)	Propose a task as challenge; Give authority to students; Provide resources.	Written and actions; Engagement in accomplish the task.

Legend: 2eTB 2nd means two episodes of teacher B in second lesson.

The teacher A have 2 patterns of teacher mediation in 2nd lesson (G2 and G3 of table 5). The teacher propose a task as challenge, give authority to students, provide resources, engage students in task, encourage the students' engagement, keep the task as challenge, correct students' engagement, monitor the engagement. In both these patterns students have three type of production and the other indicator of the students' engagement are present. The

main difference between the two patterns is that in one of them (G2) the teacher additional stimulate problematizing give information about CS and reformulate the tasks and appear an additional indicator of students' engagement: the students take the initiative. The teacher A in 1st lesson deal with an excessive number of tasks (19) and teacher made an effort to maintain the challenge during the interactions with the students. The actions of correction and monitor of student's engagement are almost inexistent during the first lesson taught by teacher A. In these patterns (G6, G7) the students' production is limited to action and oral statements (G6) or actions and written statements (G7) and only was observed that students' engagements in accomplishment of tasks.

For teacher B the main characteristics of his mediation actions are the same in both lessons: (a) propose task as challenge; (b) provide resources; (c) give information about the CS; (d) engage students in the tasks; (e) encourage students engagement; (f) give authority to students, but there are moments when takes it back, and (g) not always keep the task as challenge during the interaction's with students. The three patterns of teacher B, the students' production is limited to two forms (oral and actions – G1 and G4) or even to one form of production (G5).

Although, teacher B maintain his characteristic mediation action of give authority to his students and then take it back, the fact that during the second lesson the task was presented to students at the begging of their work, has made more effective the granting of students autonomy. Comparing the seven patterns of connections between teacher mediation and students' productive engagement we find that:

(a) When teacher stimulate problematizing the students take the initiative,

(b) Give authority to students keeping the task as challenge is necessary condition to have the three types of students' production. Unlike that it back decrease the students' production;

(c) The monitoring and correcting engagement is essential both to students have a high level of production and indicators of engagement.

4. Discussion and Conclusions

Facing the results presented previously we can infer that student's productive engagement depends of the systematic and effective use of the CS. The CS by itself may influence the student's engagement during the accomplishment of the tasks and their productivity: It depends if CS allows a strong interactivity and offer a realistic environment with possibilities of visualization of certain aspect that in the correspond material reality is not visible. The content of the lesson seems to have no effect on student's productive engagement.

The influence of the task and its management on student's productive engagement seems to be related with the fact that they need to be in appropriate number and always faced as challenge by the students. Teacher, during the interactions with students, need to maintain that challenge, in order to keep the students productive engagement. The task and its management, by themselves, don't have direct influence on student's productive engagement, but have influence on teacher mediation actions. The task must give students acceptable control over their activity and they must know exactly what they need to do to achieve an answer or solution The tasks formulation and presentation must make clear, from the beginning, what the purposes of the task are and what is expected from students to produce [15].

A manageable number of relevant tasks, presented as a challenge to students and well managed in the classroom can improve teacher mediation, especially in terms of granting autonomy given to the students, which have direct influence on their productive engagement.

Teacher mediation actions are characteristic of each teacher, and depend of his tacit professional knowledge [17] acquired over the years of teaching, but the capacity of integrate the results of the research in science education can improve his explicit professional knowledge [17] making him more attentive to face factors that can affect students productive engagement in the classroom. Teacher A with more experience of integration of research is more affective in their mediation namely concede and maintain the authority given to his student's, doesn't give constant information about how to use the CS, and correct and monitor the student's engagement.

Placing the task as a challenge to students and keep it always a challenge, provide resources to the accomplishment of the task, engage students on task, encourage student engagement, stimulate problematizing and systematically monitor student engagement without remove the authority to students are important teacher mediation actions associated with a greater productive engagement of students, where the products of the tasks are of all kinds (oral, writing and actions) and all are related with the effective use of the CS.

Teacher mediation actions like removing authority from students and don't keep the task as a challenge during the interaction with students reduces noticeably their productive engagement [12,13]. If the teacher is too

interventionist, gives too much information to students about the operation with the CS, gives immediate answers to the students questions (depriving them the opportunity to achieve by themselves the answers) can lead to situations of non-engagement or reduced productive engagement, especially in terms of emotional engagement and students initiatives.

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